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Factors Limiting Moose at High Densities in Unit 20A

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SUMMARY

This report summarizes data collected from central Unit 20A during 1 March 1996 to 19 March 1998 when moose density was high (>1 moose/km^2) and snowfall was low. Fieldwork included radiocollaring 91 newborn moose during May 1996 and 1997, 74 calves during March 1997 and 1998, 22 yearlings during March 1998, and 44 adults during March 1996. We also recaptured 28 adults during March 1997. We evaluated nutritional status of the moose population by measuring rumpfat depths and pregnancy rates and weighing calves. We regularly radiotracked moose to evaluate causes and rate of mortality.

The most notable observations were:

1 High pregnancy rates of adult cows (98%, n = 44) in 1996 and significantly decreased pregnancy rates in the Tanana Flats (61%, n = 18) in 1997.

2 Zero percent pregnancy rates among 22-month-old females (n = 22) in 1998 and no rumpfat.

3 Significantly lower 1997 pregnancy rates and rumpfat depths in Tanana Flats moose compared to the Alaska Range foothills moose.

4 Significantly lower weights of calves 10 months old in the Tanana Flats compared to those in the Alaska Range foothills, but no differences in calf birthweights.

5 High adult natural survival rates (93% annually from March 1996 to March 1998).

6 High calf survival (59% in the 1996 cohort and 58% to 300 days in the 1997 cohort), compared to 5 other Alaska–Yukon moose calf mortality studies (19 to 42%) including the use of radio collars.

Initial modeling indicates this high-density moose population (about 1.3 moose/km^2 in 1997) is continuing to increase during favorable weather. However, nutritional limitation is apparent, indicating adverse weather could initiate a significant decline in the population. No examples exist in Alaska or the Yukon in which moose maintained such a high density for an extended period in a similarly large area.

Primary management goals are to sustain a high opportunity to harvest moose and to keep the moose density above levels that combined wolf (*Canis lupus*) and bear (*Ursus arctos* and *Ursus americanus*) predation can maintain moose at low densities (0.04 to 0.42 moose/km^2, Gasaway et al. 1992). Ultimately, we hope to maintain moose at moderate to high densities without repeating the wolf control programs that initiated increases in moose to high densities in Unit 20A (Gasaway et al. 1992; Boertje et al. 1996).

To responsibly manage this population at high densities we need to know to what extent malnutrition, predation, and harvest affect population trend, particularly during adverse weather. This information is necessary, for example, to estimate optimum numbers of moose during adverse weather and sustainable yields of female moose. Maximizing harvest of female moose during favorable weather may be important to prolonging the period of high moose density.

Key words: moose, moose condition, mortality, predation, pregnancy, rumpfat, survival, twinning.

CONTENTS

BACKGROUND

Moose (*Alces alces gigas*) in Unit 20A (Fig 1) are an important resource. Moose densities in Unit 20A have been increasing during most years since initiation of an intensive aerial wolf (*Canis lupus*) control program in the late 1970s (Fig 2). The moose density in Unit 20A is approximately 6 to 7 times higher than average moose densities in similar moose-wolf-bear systems where predators have been lightly harvested (Gasaway et al. 1992). Unit 20A has had favorable weather since 1975, except during 1990–1993, and most of Unit 20A has favorable moose habitat. Black (*Ursus americanus*) and grizzly bear (*Ursus arctos)* predation in Unit 20A in the 1970s was low compared to wolf predation (Gasaway et al. 1983:30). Grizzly bears and possibly black bears were reduced in a portion of our study area by local harvests during the mid to late 1980s (Hechtel 1991; Reynolds 1994). Also, a second wolf control program was begun in Unit 20A during 1993–1994 to increase caribou (*Rangifer tarandus*) numbers (Boertje et al. 1996).

The Unit 20A moose population was estimated to be about 13,000 moose in 13,044 km^2 of moose habitat during early winter 1997 (Fig 2, 1.0 moose/km^2 ±27 % [90% CI]). Our study area in central Unit 20A (6730 km^2, Fig 1) contains about 50% of the moose habitat in Unit 20A and about 67% of the moose. For example, in 1996 we found 30% higher moose density in our study area compared to the total Unit 20A moose density. From this we surmise that the study area encompasses some of the best moose habitat in Unit 20A.

No examples exist in either Alaska or the Yukon where moose have maintained such a high density for long periods of time over a similarly large area (Gasaway et al. 1992), indicating that moose in our study area may decline substantially in the near future from the combined effects of adverse weather, browse limitation, and uncontrolled wolf and bear predation (Gasaway et al. 1992). This was the case between 1965 and 1975 when the Unit 20A moose population declined from about 1.7 to 0.23 moose/km^2 (Gasaway et al. 1983). Ill-timed harvest of cow moose also contributed to the magnitude of this decline.

Maintaining moose in Unit 20A above the level at which predation can strongly limit moose would be a significant wildlife management achievement. For example, elevated consumptive and nonconsumptive uses of moose would be ensured without repeated intensive predator control programs. Gasaway et al. (1992) concluded that moose densities are predictably low (0.04 to 0.42 moose/1000 km^2) where low harvest rates for wolves and bears prevailed for long periods in Alaska and the Yukon. Moose densities are higher in these same systems where humans significantly reduced predation.

Since the mid-1970s, Unit 20A has proven to be Alaska's most intensively managed area in terms of ADF&G costs to survey wildlife and reduce predation for promoting increased moose and caribou numbers. This management focus has broad local support, stemming primarily from a strong local tradition of hunting, awareness of the enhanced value of land with abundant wildlife, fewer hunting restrictions than elsewhere in Alaska, and awareness of the area's high densities and harvest of ungulates during the 1960s, following federal predator control in the 1950s. Approximately 3000 hunters used this area annually in the late 1980s.

The 10-year decline of moose in Unit 20A, from about 22,000 in 1965 to about 2800 in 1975, taught us several important lessons (Gasaway et al. 1983). First, Unit 20A probably cannot sustain 1.5 to 1.9 moose/km^2 through adverse, deep snowfall winters when browse availability is reduced and energetic costs of obtaining browse are high. Second, wolves strongly affected the declining moose population, as demonstrated by the wolf control program which coincided with a sustained 15% finite annual increase in the moose population (Boertje et al. 1996). Third, errors were made in managing moose in the late 1960s and early 1970s. Biologists mistakenly believed that predators killed only moose that would soon die from other causes.

Today, biologists have proven techniques for estimating moose population size and trend (Gasaway et al. 1986), and radiotelemetry allows biologists to investigate causes and rates of moose mortality and changes in reproduction. Also, the potential effects of wolf and bear predation are better understood.

A current theory on wolf predation in wolf-bear-moose systems predicts that, without periodic wolf control, wolves will increase and combined wolf and bear predation will be sufficiently high to reduce the moose population to a low level (Sinclair 1989; Messier 1994; Hayes 1995). Under an alternative theory, wolves may limit themselves at higher densities and fail to reduce the moose population. For example, large wolf territory size may restrict wolf density well below the level where wolves alone can reduce an elevated moose population to low densities. Moose may live at elevated densities for a protracted period under this theory.

The most plausible scenario is the moose population will continue to grow until adverse weather intervenes; at this time browse limitation and predation may exacerbate the decline to low levels. For example, a moose population living at an overly high density may suffer greater nutritional effects from adverse weather (Peterson and Page 1983; Messier 1995) and could potentially be accelerated to low levels by intense predation, even when moose:wolf ratios are initially relatively high (Gasaway et al. 1983). Predation can accelerate declines because of increased vulnerability of prey and underutilization of carcasses (Peterson and Page 1983). Overly high moose densities vulnerable to browse limitation are therefore cause for concern among managers, especially if the public desires that managers repeatedly control predation.

To examine these potential scenarios, we are studying the reproductive and nutritional vigor of an elevated moose population, weather variables, and the causes and rates of moose mortality in an area where predation is not annually controlled by humans (Boertje et al. 1988; Gasaway et al. 1992:Fig 9). Parameters previously correlated with moose nutritional condition include yearling and adult pregnancy rates, adult rumpfat depths, adult twinning rates, and chronology of calving (Boer 1992; Gasaway et al. 1992; Schwartz 1992). We will focus our research on calf and yearling survival and yearling reproduction because young age classes are most sensitive to limiting factors, e.g., predation, adverse weather, or food limitation. Companion projects will study dynamics of associated wolf, caribou, and grizzly bear populations.

We hope to determine what factors combine to influence the moose population and what management strategies are prudent to keep moose from returning to low densities. For example, current management options include reducing harvest during autumns following adverse winter weather and increasing harvest and habitat to reduce the possibility of food limitation.

OBJECTIVES

- Review literature on 1) moose biology and ecology at high densities; 2) indices to nutritional status of ungulates; 3) models of ungulate population dynamics; 4) predator–prey ratios in relation to population dynamics of moose, caribou, sheep (*Ovis dalli*), wolves, and grizzly bears; 5) predator–prey relationships in multiprey, multipredator systems; and 6) population and harvest data on moose, caribou, sheep, wolves, and bears in Unit 20A.

- Estimate and evaluate the usefulness of several reproductive and condition indices for moose in Unit 20A.

- Determine causes and respective rates of mortality among radiocollared moose of various age classes in Unit 20A.

- As part of an initial graduate student project, we hope to test the hypotheses that a relationship exists between dam condition and mortality of calves and that a relationship exists between neonatal variables of condition and mortality of calves. A second graduate student project will study moose movements and dispersal rates and evaluate browse availability in the Tanana Flats and Alaska Range foothills.

STUDY AREA

This study is being conducted in the central portion of Unit 20A (6730 km^2, Fig 1) where moose densities are highest. This area is bounded to the north by the Tanana River, to the west by Tatlanika Creek, to the south by the crest of the Alaska Range, and to the east by the Little Delta River. Unit 20A was described previously by Gasaway et al. (1983) and Boertje et al. (1996).

METHODS

ADULT CAPTURE, CONDITION INDICES, RADIOTELEMETRY, AND MORTALITY

During 1–4 March 1996, we immobilized 22 adult female moose (>33 months old) in the Tanana Flats and 22 adult female moose and 1 yearling female in the Alaska Range foothills. During 10–13 March 1997 we recaptured 16 moose from the Tanana Flats and 12 moose from the Alaska Range foothills to reevaluate condition, and we captured 2 new adult female moose in the Tanana Flats. We immobilized these moose with 4.0 to 4.5 mg (1.33 to 1.5 cc) carfentanil citrate (Wildnil®, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) and 150 to 167 mg (1.5 to 1.67 cc) xylazine hydrochloride (Anased®, Lloyd Laboratories, Shenandoah, Iowa, USA), administered intramuscularly via a 3 cc projectile syringe (2.9 cm needle) fired from an extra long-range Palmer Cap-Chur® rifle (Douglasville, Georgia). We injected 400 to 450 mg (8 to 9 cc) of naltrexone hydrochloride (Trexonil®, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) intramuscularly to reverse the effects of carfentanil citrate. Only 1 of 74 immobilized moose died, and this moose was near death when darted. In 1996 we used 2 Robinson R-22 helicopters for capture, allowing simultaneous processing and darting. In 1997 and 1998, we used a Robinson R-44 helicopter for capture.

During 11–12 March 1998, we recaptured 22 22-month-old moose that were initially collared as 10-month-olds. No mortality was observed using the following drug doses: 3 mg carfentanil citrate and 100 mg xylazine hydrochloride delivered via a 2 cc projectile syringe (2.9 cm needle) and reversed with 300 mg (6 cc) naltrexone hydrochloride and 400 mg (4 cc) tolazaline hydrochloride (Tolazine®, Lloyd Laboratories, Shenandoah, Iowa, USA), given intramuscularly except for 2.5 cc given intravenously.

When moose were immobilized, we 1) measured neck girth, hindfoot length, and total length along the dorsal body contour from the hairless patch on the nose to the tip of the tail bone, 2) measured depth of rumpfat on the rump via ultrasound (Stephenson et al., in press), 3) extracted a canine tooth as needed to determine age from cementum annuli (Matson's Laboratory, Milltown, Montana, USA), and 4) collected 50 cc of blood from the jugular vein. R Zarnke (ADF&G, Fairbanks) processed blood samples. Serum was analyzed for antibodies (ADF&G, unpublished data) and pregnancy-specific protein B (PSPB, Bio Tracking, Moscow, Idaho, USA). In 1996 serum was analyzed for 22 constituents (standard blood-serum profile, Fairbanks Memorial Hospital) and the acute phase protein haptoglobin (L Duffy, University of Alaska Fairbanks). T Stephenson (ADF&G, Soldotna) diagnosed pregnancy status using transrectal ultrasonography in 1996 to compare with PSPB levels in blood samples.

We deployed Advanced Telemetry Systems (ATS, Isanti, Minnesota, USA) radio collars (Model 2-9D3). Pulse rate of collars doubled when collars remained motionless for 5 hours (motion sensing switch). We radiotracked adults daily in May and early June to detect newborn calves and listened to adult signals approximately monthly to monitor mortality rates. We used criteria and techniques described by Boertje and Gardner (1998) to evaluate causes of death.

SHORT-YEARLING CAPTURE, CONDITION INDICES, RADIOTELEMETRY, AND MORTALITY

We immobilized 17 short yearling female moose (10 months old) in the Tanana Flats and 17 in the Alaska Range foothills during 9–19 March 1997. During 3 and 9 June 1997, we immobilized 4 yearling female moose (12 months old) in the Tanana Flats with a lighter drug dose because 4 calves died following capture in March. We immobilized March calves with 1.5 mg carfentanil citrate and 120 mg xylazine hydrochloride, administered intramuscularly via a 2 cc projectile syringe (1.9 cm needle) fired from an extra long range Palmer Cap-Chur® rifle. We injected 150 mg of naltrexone hydrochloride intramuscularly to reverse effects of the carfentanil citrate.

During 13–16 March 1998, we immobilized 20 short-yearlings in the Tanana Flats and 20 in the Alaska Range foothills. No mortality was observed using the following drug doses: 1.2 mg carfentanil citrate and 60 mg xylazine hydrochloride, delivered via a 1 cc projectile syringe and reversed with 150 mg (3 cc) naltrexone hydrochloride and 250 mg (2.5 cc) tolazaline hydrochloride, given intramuscularly except for 1 cc given intravenously.

When moose were immobilized, we 1) measured neck girth and total length along the dorsal body contour from the hairless patch on the nose to the tip of the tail bone, 2) measured depth of rumpfat via ultrasound (Stephenson et al., in press), 3) weighed the moose with an electronic, calibrated strain gauge using an R-44 helicopter to lift the moose, and 4) collected 50 cc of blood from the jugular vein.

We deployed ATS radio collars (model 9-6VC). Extra overlapping collar belting and an attached bungie accommodated growth of yearlings. Pulse rate of collars doubled when collars remained motionless for 5 hours (motion sensing switch). We radiotracked yearlings approximately twice per month to monitor mortality rates.

NEWBORN CALF CAPTURE, CONDITION INDICES, RADIOTELEMETRY, AND MORTALITY

We monitored pregnant, collared females daily from fixed-wing aircraft (Piper PA-18 Supercub) between 14 May and 3 June 1996 and 16 May and 6 June 1997. We noted births during early morning fixed-wing flights and captured calves in the afternoon. We captured 46 calves between 14 May and 3 June 1996, 28 from radiocollared cows and 18 from unmarked cows. In 1997 we captured 45 calves, 25 from radiocollared cows and 20 from unmarked cows between 16 May and 9 June. We distributed collars both geographically and temporally to mimic the calving of collared cows.

We captured newborns using a Jet Ranger 206 helicopter during 1996. During 1997 we captured most newborns with an R-44 helicopter. Cow-calf pairs were usually in clearings that permitted landing within a few meters of calves, and disturbance from the helicopter was usually sufficient to frighten dams away from the capture crew. If the cow-calf pair was not in or near clearings, the capture crew (with radio communication) exited the helicopter in the closest landing area. The helicopter then hovered above the calf in an attempt to frighten the dam away. We monitored all captures from fixed-wing aircraft. Some calves could not be captured without undue risk to the capture crew. If a calf of a radiocollared dam could not be captured, we captured a substitute calf from an uncollared dam in the same area. Capture success was most dependent upon the skill level of the helicopter pilot. We released calves in less than 5 minutes (even if data collection was not complete) to minimize separation time. We used latex gloves and individual weighing and restraint bags (nylon bushel bags) to minimize transfer of scent. When twins were present, the capture crew captured and restrained both calves but processed only 1, releasing both simultaneously.

We determined sex of calves and weighed calves by placing them in a bag and suspending them with a 25 kg Chatillon (Kew Gardens, New York) spring scale. To estimate birthweights, we subtracted 1.6 kg for each day >0.5. This correction factor was based on regression models using weights of known age calves. Due to uncertainty in estimating age beyond 4 days, birthweights obtained from calves estimated to be older than 4 days were omitted from statistical analysis involving birthweights. We collected 3 cc of blood from the jugular vein. L Duffy (University of Alaska Fairbanks) analyzed serum samples for the acute phase protein haptoglobin during 1996.

During 1996 we deployed radio collars weighing 180 g each (ATS model 8 transmitters, 1.5 hr motion-sensing switch), constructed from 2 layers of 10 cm PEG® (Franklin Lakes, New Jersey) elastic bandage (Osborne et al. 1991). During 1997 we deployed radio collars (200 g) constructed from 4 layers of elastic bandage. The day following capture we visually radiolocated calves to assure the pair rebonded. Following visual confirmation of rebonding, we listened to calf signals to determine survival; flights were daily until 13 June and every other day until 30 June, after which the tracking interval gradually increased. Using a helicopter, we investigated mortality signals immediately. We used criteria and techniques described by Adams et al. (1995) and Boertje and Gardner (1998) to evaluate causes of death.

Eleven calves from the 1996 cohort slipped collars: 8 from collared dams and 3 from uncollared dams. We immediately censored calves of uncollared dams, but visually located collared dams to evaluate calf mortality rates. If the calf was not with the collared dam on 3 consecutive flights, we assumed the calf died. No calves from the 1997 cohort have slipped collars.

STATISTICAL ANALYSES

We used students' 2-tailed *t*-tests for pooled variances to analyze tabular data unless otherwise specified. To identify potential relationships between 22 serum constituents (standard blood profile) and rumpfat depth, we used multiple regression models (α to enter and stay = 0.15). We used regression to evaluate whether relationships existed between calving date and rumpfat depth. We estimated survival rates for calves using Kaplan-Meier staggered-entry design for telemetry studies (Pollock et al. 1989). We used logistic regression to model the influence of the independent variables of neonate condition (birthweight, birth date, sibling status, and sex) on the dependent variable calf survival. We also used logistic regression to model the influence of the independent variables of cow condition (cow age, maximum rumpfat depth, midpoint rumpfat depth, and dam collaring location) on the dependent variable calf survival (Adams et al. 1995). Survival was broken down into 5 time intervals (1–30, 1–60, 1–140, 1–240, and 1–365 days); α for entry and inclusion into the model was set at 0.10, and a stepwise procedure was used. All analyses, except Kaplan–Meier estimates (Pollock et al. 1989) and *z*-test for proportions (Remington and Schork 1970), were completed using the statistical program SAS (SAS Institute Inc., Cary, North Carolina, USA).

RESULTS AND DISCUSSION

ADULT FEMALE AGE STRUCTURE

A histogram of adult age structure (Fig 3) indicates the study population was well represented by young and middle-aged females in 1996. Mean adult female age was 6.8 years old (s = 3.28, n = 45) in 1996 using 1996 captures (n = 44) and a backdated 1997 capture. The oldest moose was estimated to be 13 years old (Matson's Laboratory, Milltown, Montana, USA).

ADULT REPRODUCTIVE INDICES

Given the high density of our study population and data summarized by Gasaway et al. (1992:Table 5), we predicted adult pregnancy rates of about 76 to 84% or lower as observed for moose populations near K carrying capacity. In contrast, 43 (98%) of 44 adult females were pregnant in 1996. This rate is higher than most populations reported to be below K carrying capacity and indicates the study population is below K carrying capacity when snow is scarce (Gasaway et al. 1992:Table 5). However, in 1997 an overall study area pregnancy rate of 77% (n = 30) was observed, indicating the population was near K carrying capacity. This annual variation in pregnancy rates of collared adults will be discussed as more data become available. We want to test whether raising a calf significantly reduces the chance of a subsequent pregnancy.

The spatial distribution of pregnancy rates indicates the Tanana Flats portion of this population was experiencing less favorable environmental factors in 1997. Alaska Range foothills moose experienced 100% pregnancy (n = 12) in 1997 compared to only 61% pregnancy (n = 18) among Tanana Flats moose; this difference was significant (P = 0.001, z-test for proportions, z = 3.39).

Detecting pregnancy using transrectal ultrasonography and PSPB analyses gave identical results in 1996. Therefore, we used only PSPB analyses to detect pregnancy in latter collections.

Twinning occurred in 11 (31%) of 35 pregnant radiocollared adult females ≥36 months old in 1996 and 3 (10%) of 29 pregnancies in 1997. The observed 1996 adult twinning rate (31%) falls within the range (23 to 90%) reported for moose of similar ages from populations below K carrying capacity (Gasaway et al. 1992:Table 5). The 1997 twinning rate (10%) falls within the range (1 to 25%) reported for moose from populations near K (Gasaway et al. 1992:Table 5). Weather events are likely a major factor influencing annual differences in productivity of moose populations, and this relationship will be studied in more detail as more data become available.

We are continuing standard aerial spring twinning rate surveys and will compare the results with twinning rates of collared adults when more data are available on pregnancy rates of 24-month-old females. The 1996 twinning rate among 35 pregnant radiocollared females ≥3 years old was 31% compared with standard spring twinning surveys of 18% (n = 40 random females observed with calves). In 1997 the observed twinning rates were similar: 10% (n = 29) using visual location of radiocollared cows and 12% (n = 26) using standard spring twinning surveys.

ADULT RUMPFAT DEPTHS

Depth of rumpfat is a potential index by which condition can be measured over time or among populations. During 1997 we observed significantly less rumpfat on Tanana Flats cows than on Alaska Range foothills cows (Table 1). Rumpfat depth was also lower in 1997 compared to 1996 among Tanana Flats cows. These trends indicate that Tanana Flats moose may be experiencing less favorable environmental factors compared to Alaska Range foothills moose.

Our average rumpfat values are less than Stephenson (1995) reported for moose below K carrying capacity on the Copper River Delta during March 1993 and 1994. However, the Copper River Delta has a much milder climate than Unit 20A. Comparable published data for March from Interior Alaska and the Yukon are lacking at this time.

As expected, we found significant relationships between March rumpfat depths and reproductive status. Mean maximum depth of rumpfat was significantly greater (P = 0.001, t-test) among pregnant versus nonpregnant adult cow moose (Table 2). Mean maximum depth of rumpfat was also significantly greater (P = 0.006, t-test) for dams giving birth to twins versus those with singletons (Table 3). No relationship existed between rumpfat depths and cow age.

We also found that the fattest dams produced on average the heaviest calves. Regression indicated birthweight of singleton neonate moose was positively (P = 0.0003, R^2 = 0.29) related to March rumpfat of their dam (Fig 4).

SHORT-YEARLING WEIGHTS AND RUMPFAT DEPTHS

The overall mean weight of 10-month-old calves was 159 kg in 1997 and 160 kg in 1998 (Table 4). Significantly lower mean weights occurred in the Tanana Flats compared to the Alaska Range foothills as expected, because adults had less rumpfat and lower pregnancy rates in the flats in 1997. No rumpfat was detected on any 10-month-old calves sampled (n = 22) in 1997. We know of no other published data on 10-month-old moose in Alaska or the Yukon with which to compare these data. However, several researchers are currently collecting these data (W Testa in Unit 13, ADF&G; L Adams in Denali National Park, USGS; and B Shults in the Noatak River, NPS).

NEWBORN CALF WEIGHTS

We expected birthweights to provide a relatively sensitive index to winter and spring maternal and range condition and that elevated birthweights would occur among the Alaska Range foothills subpopulation, because these dams had more rumpfat than Tanana Flats dams. However, birthweights may provide only a nonsensitive relative index to winter and spring conditions. For example, Ballard et al. (1996) found no increase in newborn calf weights following mild winter conditions. Likewise, we found no significant differences in newborn singleton or twin birthweights with regard to dam collaring location (Tanana Flats versus Alaska Range foothills, P >0.18, t-test) or capture year (P >0.20, t-test).

Comparable data on calf birthweights from Interior Alaska and the Yukon are lacking at this time, making interpretation of birthweight data speculative. However, our calves weighed slightly more than captive calves born on a high plane of nutrition. Schwartz and Hundertmark (1993) reported mean birthweights of 13.5 kg for twin calves and 16.2 kg for single calves <24 hours old at the Moose Research Center (MRC) on the Kenai Peninsula, Alaska. Our mean birthweights were 13.7 kg (s = 1.6, n = 15) for twins and 16.9 kg (s = 2.5, n = 65) for singletons.

As expected, twin calves weighed significantly less than singletons (P = 0.0001, males and females pooled, t-test) and female singletons weighed significantly less than males (P = 0.005, t-test, Table 5). Contrary to our findings, Schwartz and Hundertmark (1993) found no significant difference between male and female calf weights. To our knowledge we have reported the first statistical difference in birthweights between male and female moose calves. Sexual dimorphism in weight of neonates has previously been reported for white-tailed deer (Verme 1989), mule deer (Kucera 1991), and red deer (Clutton-Brock et al. 1981).

BLOOD PARAMETERS OF CONDITION

The acute phase protein haptoglobin in serum samples may be helpful in distinguishing stressed from nonstressed mammals (Duffy et al. 1993; Zenteno-Savin et al. 1997). No detectable levels of haptoglobin were present in any of our calf (*n* = 43) or adult (*n* = 44) serum samples from 1996. Samples from 1997 have not yet been analyzed for haptoglobin.

With the blood obtained from adult female moose in 1996, we attempted to identify potential relationships between 22 serum constituents (standard blood profile) and rumpfat depth using multiple regression models. A model using creatinine and AST met all the necessary criteria but accounted for only 33.7% (adjusted R^2) of the variability observed. We conclude, at this time, that standard serum constituents are not useful indicators of rumpfat reserves in moose. More data are forthcoming.

CALVING DATE AND CORRELATIONS WITH COW RUMPFAT, AGE, AND MORPHOLOGY

Reduced snow depths during winter 1995–1996 may have contributed to earlier calving in 1996 compared to 1997. During 1996, 35 births of radiocollared cows were observed between 12 and 27 May, median date of calving was 19 May, and the greatest number of births (*n* = 5) occurred on 20 May. During 1997 29 births of radiocollared cows were observed between 14 May and 3 June, median calving date was 22 May, and the greatest number of births occurred on 20 and 21 May (*n* = 3 each). Cumulative proportions of calves born during each calving period are depicted in Figure 5. Historical data from this study area indicate these are typical moose calving dates. Only following adverse winters with deep snow has calving in this area been delayed until June (ADF&G, unpublished data).

If adverse winter weather can delay calving or if poor autumn condition delays conception, we would predict that dams with the earliest births might have the greatest March fat reserves or body size. As expected, regression indicated a significant (*P* = 0.0398) negative relationship (slope = -1.355) between calving date and maximum March rumpfat depth. For this model we tested for an interaction between maximum March rumpfat depth and year but did not find any interaction (*P* = 0.5488). Therefore, we pooled years giving the model a common slope but separate intercepts. Data are needed following adverse winter weather to further study this relationship.

ADULT NATURAL MORTALITY AND HARVEST

During the first year (1 March 1996–28 February 1997) of this study, predators killed 3 (7%) of 44 radiocollared adult female moose. Wolves killed 1 between late April and mid May 1996 and 1 during November 1996. A grizzly bear killed 1 during June 1996. Additionally, a trapper killed 1 in a wolf snare during January 1997. During the second year (1 March 1997–28 February 1998), predators killed 2 (5%) of 43 radiocollared adult female moose. Wolves killed both moose during March 1997. In addition, 1 moose died following recapture in early March 1997. This moose was near death during recapture, and we assume it would have died from natural causes had we not intervened.

Hunters took a nominal harvest of cows in the study area during autumns 1996 and 1997. During the first legal cow seasons since 1974, the department issued 300 drawing permits annually with 63 cows reported harvested each year. The 1996 reported bull harvest totaled 594 for a combined reported harvest rate of 5% of the prehunt population. The harvest rate totaled 6%, if we multiply the reported bull harvest by 1.15 to account for unreported harvest and mortally wounded moose (Boertje et al. 1996). Boertje et al. (1996) reported a 4% average annual harvest rate in Unit 20A during the previous 20 years. Data are not yet available for the 1997 bull harvest.

YEARLING MORTALITY

Seven of 33 (21.2%) radiocollared yearlings died from predation during the first year of data (10 March 1997 to 9 March 1998). Three yearlings were killed by wolves during April and May, 1 by wolves and 1 by a bear (species unknown) in June, 1 by a black bear in July, and 1 by wolves in January. No nonpredation mortality was observed.

CALF MORTALITY

We collared 91 calves during 1996 and 1997. Eight calves died from capture-induced reasons (trampling by dam following release or abandonment); we censored these calves from the analysis. One transmitter failed within a few weeks of deployment, and 1 failed a few months later.

The 1996 radiocollared calf cohort experienced the highest annual survival rate (59%, Fig 6) among Alaska–Yukon moose calf mortality studies conducted to date. Using similar techniques, biologists previously reported annual calf survival rates were 19% (Larsen et al. 1989), 25% (Gasaway et al. 1992), 29% (Osborne et al. 1991), 32% (Ballard et al. 1991), and 42% (Franzmann et al. 1980). As of mid March 1998, the survival rate among the 1997 cohort of collared calves was 58% (Fig 7).

In subsequent reports we will compare the mortality rates of singleton calves among studies because twin calves experienced significantly lower survival rates compared to singletons ($P < 0.05$, log-rank test, Fig 8). Osborne et al. (1991) previously reported lower survival of twins. Protecting 2 calves from predators is likely more difficult than protecting a single calf (Stephenson and Van Ballenberghe 1995).

Predation was by far the major proximate cause of death in this and all previous moose calf mortality studies. Wolves, grizzly bears, and black bears killed about equal proportions of calves in this study (Fig 9). In previous moose calf mortality studies, either black or grizzly bears were the major predator.

In addition to mortality detected using radiocollared calves, perinatal mortality apparently occurred in 7 (17%) of 42 births in 1996 and 3 (13%) of 23 births in 1997. These were births that were never observed during daily flights. Births were assumed based on pregnancy data, i.e., transrectal ultrasonography and PSPB analyses in 1996 and PSPB analyses in 1997. We define perinatal mortality as mortality during the first 24 hours after birth. Causes of these deaths are difficult to determine. Predation is probably only partly responsible for these deaths (Whitten et al. 1992; Boertje and Gardner 1998:14). We observed 2 stillborn calves (1 each in 1996 and 1997), 1 from a set of twins and 1 apparently a singleton, both born to radiocollared cows.

RELATIONSHIP BETWEEN NEONATE CONDITION AND CALF MORTALITY

We studied the relationship between calf survival and birthweight, birth date, and sex for singleton calves for 1996 and 1997 data combined. No variables entered the logistic regression model for the survival interval 1 to 30 days. These data indicate that all calves are equally vulnerable to mortality factors common to this first month of life. However, for survival intervals age 1 to 60 days and 1 to 140, birthweight entered the model ($P = 0.011$ and 0.007, respectively), indicating increased mortality of lighter calves; parameter estimates were -0.26 and -0.25, respectively. No variables entered the model for the interval 1 to 240 days. For survival from age 1 to 365 days, birth date entered the logistic regression model ($P = 0.086$), with a parameter estimate of 0.212, indicating increased mortality of later born calves (only 1996 data were available for this analysis). These data indicate the smallest calves in a high-density moose population may be more vulnerable to predation during their first year.

No variables entered the logistic regression model analyzing twin calf mortality. This may be caused by small sample size.

RELATIONSHIP BETWEEN ADULT CONDITION AND CALF MORTALITY

Preliminary analysis of the data supports the hypothesis that no relationship exists between dam condition (age, fat reserves, and collaring location) and mortality of their calves within the range of values observed. Neither dam age, fat reserves, nor dam collaring location entered the logistic regression model during any time interval. However, a weak indirect relationship between dam condition and calf survival may exist, based on the observed relationship between dam rumpfat and calf weight (Fig 4). More values are needed from more nutritionally stressed moose to further study this relationship.

CONCLUSIONS

Adult rumpfat data and 10-month-old calf weights indicate the Tanana Flats moose are experiencing less favorable environmental conditions than moose in the Alaska Range foothills. These preliminary data indicate moose in the Tanana Flats exhibited signs of reaching K carrying capacity during the mild winter of 1996–1997. Alaska Range foothills moose, in contrast, are probably below K during mild winters despite similar high densities in winter.

Data from Isle Royale and Norway indicate that moose tend to overshoot the long-term carrying capacity of their range, unless adverse weather and predation intervene (Page 1989; Saether et al. 1996). Boertje et al. (1996) concluded that given the wide variation in snow conditions and effects of predation, the concept of a long-term stable carrying capacity may be inappropriate in this study area. We have data from only 3 mild winters, and we expect to see much more variability in condition following a winter of moderate to heavy snowfall.

During 1995–1998 nutritional limitation and mortality were insufficient to stabilize or decrease the moose population. ADF&G is actively pursuing prescribed burns in Unit 20A to improve moose habitat, and we may pursue more extensive cow hunts in the near future to increase hunting opportunity when survival of cows is high.

A primary goal is to provide maximum sustained opportunity to harvest moose at moderate to high densities, but without repeating the previous wolf control programs. A priority is to keep the moose density from falling to levels that predation can limit the population (Gasaway et al. 1983, 1992). We hope to determine an optimum range of moose numbers for Unit 20A. Ideally, we want to see moose at high numbers but not so high that severe declines occur following adverse weather.

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Figures

Figure 1 Shaded portion is the 6730-km^2 study area in central Unit 20A. About 67% of the moose in Unit 20A reside in the study area. Unit 20A contains about 13,044 km^2 of moose habitat.

Figure 2 Moose density estimates (± 90% CI) in 13,044 km^2 of moose habitat in Unit 20A, Interior Alaska, 1978–1997. Data from 1978–1994 are described by Boertje et al. (1996).

Figure 3 Age structure of 45 radiocollared moose ≥2 years old, central Unit 20A, March 1996. Data are from cementum annuli of canines (Matson's Laboratory, Milltown, Montana).

Figure 4 Relationship between singleton calf birthweight in May and depth of dam's rumpfat in March, central Unit 20A, 1996 and 1997 data combined, $P = 0.0003$, slope = 1.60, $R^2 = 0.29$.

Figure 5 Cumulative proportion of moose calves born to radiocollared dams during calving seasons 1996 and 1997, central Unit 20A

Figure 6 Survivorship of radiocollared moose calves (n = 42) from birth in May 1996 through mid May 1997, central Unit 20A

Figure 7 Survivorship of radiocollared moose calves (n = 41) from birth in May 1997 through mid March 1998, central Unit 20A

Figure 8 Survivorship of radiocollared singleton (n = 70) and twin (n = 13) moose calves from birth in May 1996 and 1997 through mid March 1998, Unit 20A. Survivorship functions were significantly different (P <0.05), log-rank test.

Figure 9 Causes of death among 34 radiocollared moose calves that died during 1996 and 1997 in central Unit 20A. Nonpredation mortality included 1 calf that died from drowning/exposure (Sep–Oct), 1 calf that died from malnutrition (Feb), and 1 calf that died from injuries inflicted by a moose during the rut.

Tables

Table 1 Average rumpfat depths of adult female moose from the Tanana Flats and adjacent Alaska Range foothills, March 1996 and 1997, central Unit 20A

	Tanana Flats						Alaska Range foothills					
	1996			1997			1996			1997		
Parameter	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
Adult rumpfat at midpoint (cm)	0.7[a]	0.5	20	0.2[ba]	0.3	18	0.5	0.4	22	0.7[b]	0.4	12
Adult rumpfat at maximum (cm)	1.7[c]	1.1	21	0.5[dc]	0.6	18	1.4	1.0	22	1.7[d]	0.7	12

[a] Difference significant (P = 0.0004), t-test.
[b] Difference significant (P = 0.0004), t-test.
[c] Difference significant (P = 0.0001), t-test.
[d] Difference significant (P = 0.0001), t-test.

Table 2 Average rumpfat depths for pregnant and nonpregnant adult female moose, March 1996 and 1997, central Unit 20A

	Rumpfat at midpoint (cm)			Rumpfat at maximum (cm)		
Status	$\bar{x}$	s	n	$\bar{x}$	s	n
Pregnant adult cows	0.55[a]	0.43	64	1.44[b]	0.99	65
Nonpregnant adult cows	0.05[a]	0.11	8	0.33[b]	0.57	8

[a] Difference significant (P = 0.0001), t-test for unequal variances.
[b] Difference significant (P = 0.001), t-test for unequal variances.

Table 3 Average rumpfat depths in March from moose dams with singleton versus twin newborn calves in May 1996 and 1997, central Unit 20A

	Rumpfat at midpoint (cm)			Rumpfat at maximum (cm)		
Status	$\bar{x}$	s	n	$\bar{x}$	s	n
Cow with singleton	0.51[a]	0.42	42	1.29[b]	0.93	42
Cow with twins	0.81[a]	0.43	11	2.16[b]	0.92	12

[a] Difference significant (P = 0.0409), t-test.
[b] Difference significant (P = 0.0058), t-test.

Table 4 Average weights of female calves 10 months old in the Tanana Flats and adjacent Alaska Range foothills, March 1997 and 1998, central Unit 20A

	Weights of 10-month-old female calves (kg)								
	Tanana Flats			Alaska Range foothills			Combined Areas		
Year	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
1997	154.2[a]	25.0	17	164.5[a]	24.7	17	159.2	25.0	34
1998	150.9[b]	20.9	20	169.4[b]	19.1	20	160.2	21.9	40
Combined years	152.4[c]	22.6	37	167.2[c]	21.7	37	159.8	23.2	74

[a] Difference significant (P = 0.117), one-tailed t-test.
[b] Difference significant (P = 0.003), one-tailed t-test.
[c] Difference significant (P = 0.003), one-tailed t-test.

Table 5 Average birthweights for singleton and twin newborn moose, 1996 and 1997, central Unit 20A

	Singleton birthweights (kg)[a]						Twin birthweights (kg)[a]					
	Males[b]			Females[b]			Males			Females		
Year	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
1996[c]	18.4	3.0	9	16.4	2.6	17	14.1	2.4	4	13.5	1.4	6
1997[c]	17.6	2.2	15	16.2	2.3	21				14.4	1.1	3
Combined (1996–1997)	17.9	2.5	24	16.3	2.4	38	14.1	2.4	4	13.8	1.3	9

[a] Male singletons weighed significantly more than male twins in 1996 (P = 0.0294) and combined 1996–1997 (P = 0.0092). Female singletons weighed significantly more than female twins in 1996 (P = 0.0174) and combined 1996–1997 (P = 0.0049), t-test.
[b] Male singletons weighed significantly more than female singletons in 1996 (P = 0.0893), 1997 (P = 0.0779), and combined 1996–1997 (P = 0.0144), t-test.
[c] No significant difference between 1996 and 1997 birthweights (P >0.2) within sex or sibling status, t-test.